

# Mechanisms of exclusive meson production at high energies

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**Abstract.** I discuss mechanisms of exclusive production of mesons at high energies. Some illustrative examples for the FNAL Tevatron and CERN LHC as well as for lower energies are shown.

**Keywords:** Exclusive production of mesons, QCD diffraction, differential distributions

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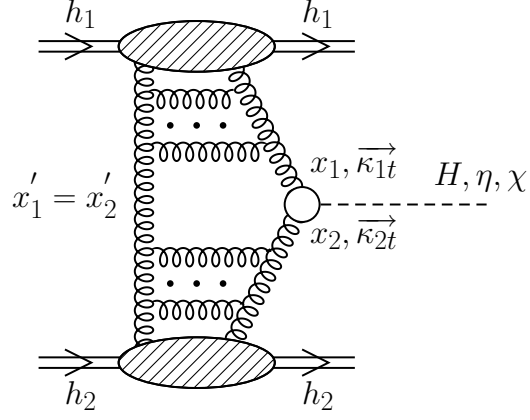
## INTRODUCTION

The exclusive production of mesons was studied in the past mostly close to the kinematical threshold. The Tevatron is a first accelerator which opens a possibility to study the (semi)exclusive production of mesons at high energies. A similar program will be carried out in the future at just being put into operation LHC. Here I briefly review several mechanisms of exclusive meson production studied recently by the Cracow group (the details can be found in [1, 2, 3, 4, 5]). In general, the mechanism of the reaction depends on the quantum numbers of the meson and/or its internal structure. For heavy scalar mesons (scalar quarkonia, scalar glueballs) the mechanism of the production, shown in Fig.1, is exactly the same as for the diffractive Higgs boson production extensively discussed in recent years by the Durham group [6]. The dominant mechanism for the exclusive heavy vector meson production is quite different. Here there are two dominant processes shown in Fig.2. When going to lower energies the mechanism of the meson production becoming more complicated and usually there exist more mechanisms. For illustration in Fig.3 I show a new mechanism of the glueball production proposed recently in Ref.[5].

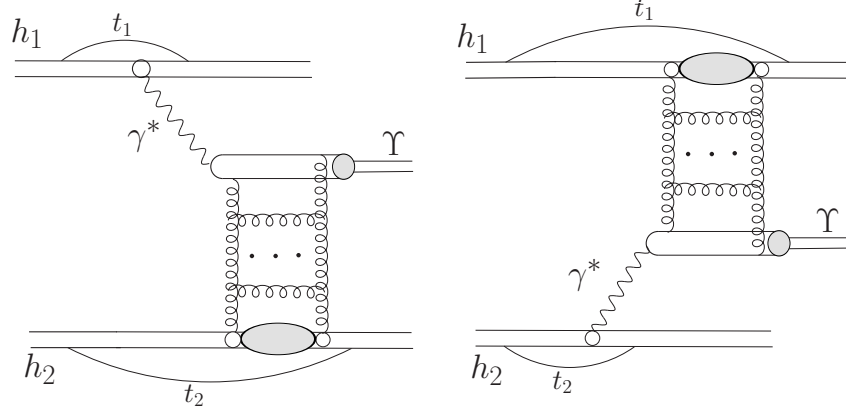
## SOME EXAMPLES

Recently we have calculated differential cross sections in several reactions (including different mechanisms):

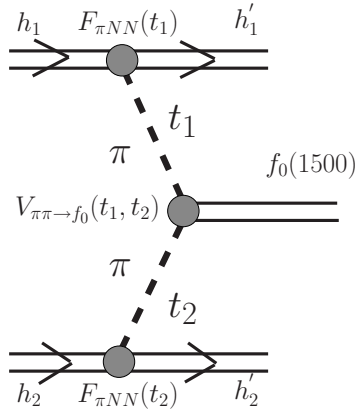
- $pp \rightarrow pp\eta', pp \rightarrow pp\eta_c$  ( IP IP +  $\gamma\gamma$  )
- $pp \rightarrow pp\chi_c(0)$  ( IP IP +  $\gamma\gamma$  )
- $pp \rightarrow pp f_0(1500)$  ( IP IP +  $\pi^+\pi^-$  )
- $pp \rightarrow pp J/\psi$  ( IP  $\gamma$  +  $\gamma$  IP )
- $pp \rightarrow pp \Upsilon$  ( IP  $\gamma$  +  $\gamma$  IP )



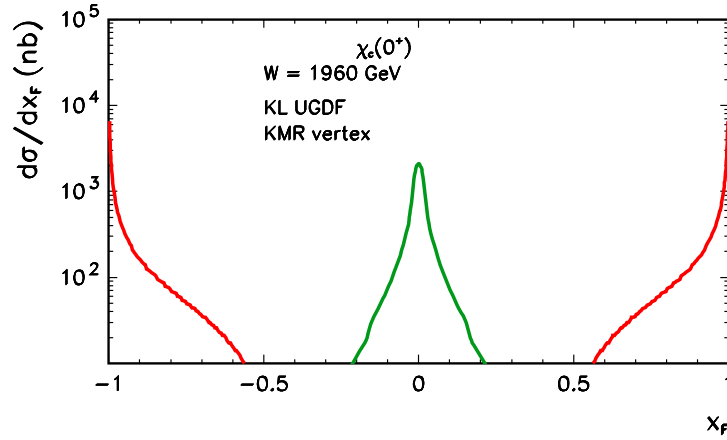
**FIGURE 1.** A sketch of the bare QCD mechanism of exclusive heavy scalar meson production.



**FIGURE 2.** Two basic QED  $\otimes$  QCD mechanisms of exclusive heavy vector meson production.



**FIGURE 3.** A sketch of the bare QCD mechanism of exclusive heavy scalar meson production.



**FIGURE 4.** Distribution in Feynman  $x_F$  of  $\chi_c(0)$  meson and associated proton (left bump) and antiproton (right bump) for the Tevatron energy.

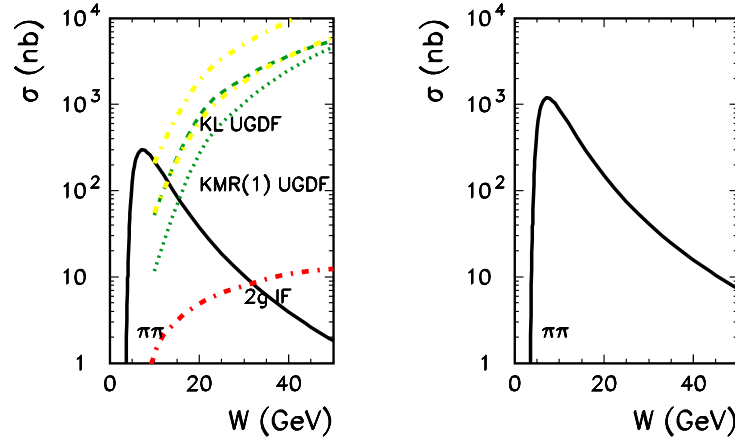
- $pp \rightarrow pp\pi^+\pi^-$  ( (IP + IR)  $\otimes$  (IP + IR) )

The details of the formalism as well as a detailed analysis of differential distribution in longitudinal and transverse momenta can be found in the original papers [1, 2, 3, 4, 5]). Here I wish to flash only some illustrative examples.

## Scalar meson production

Let us start with the production of scalar particles. In Ref.[3] we discussed in detail the production of scalar  $\chi_c(0)$  meson. Here the dominant mechanism is exactly the same as for celebrated recently diffractive production of Higgs boson. A study of this reaction can be an alternative for inclusive searches for the Higgs boson at LHC. In order to show the general features of the exclusive diffractive production in Fig.4 I show distribution in Feynman  $x_F$  of  $\chi_c(0^+)$  mesons (the middle bump) as well as distributions of the associated proton (left bump) and antiproton (right bump) for  $W = 1960$  GeV. In this calculation the unintegrated gluon distribution (UGDF) ala Kharzeev-Levin were used [3]. As discussed in Ref.[3] the cross section strongly depends on UGDF used. A clear gaps in  $x_F$  between the meson and associated nucleons can be seen. The gaps in  $x_F$  translate into gaps in rapidity. Generally the diffractive production of single mesons can be characterized by rapidity gaps. Can this be used as a criterion for selecting appropriate events? It would be useful for potential experiments to calculate cross section for inclusive double diffraction of  $\chi_c(0)$  mesons to verify if the large rapidity gap criterion can be used to pin down the exclusive channel.

It seems that the dominant mechanism of the glueball production at high energies should be the same as for the  $\chi_c(0)$  meson. If there is appreciable gluonic component in a meson the ladder gluons could (should) strongly couple to the meson. In Ref.[5] we concentrated rather on the intermediate and low energy regime. In addition to the

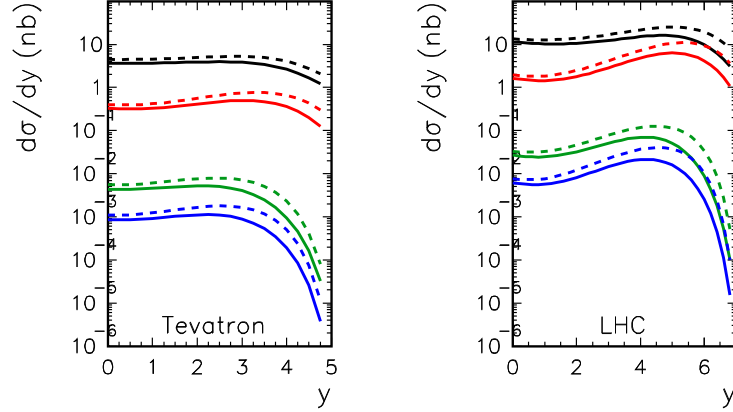


**FIGURE 5.** Integrated cross section as a function of initial energy. The solid line corresponds to the pion-pion fusion whereas the dashed and dotted line to the diffractive QCD mechanism with different UGDFs.

QCD diffractive mechanism we considered the two-pion fusion. It seems that this new mechanism may dominate close to threshold. This can be checked in the future with the PANDA detector at the complex FAIR planned at GSI Darmstadt. In the  $p\bar{p} \rightarrow p\bar{p}f_0(1500)$  channel the pionic mechanism dominates close to threshold, while the QCD diffraction takes over at larger energies. In the  $p\bar{p} \rightarrow n\bar{n}f_0(1500)$  channel the pion-exchange mechanism may dominate in a broader range of energies.

## Vector meson production

Because of their quantum numbers vector mesons cannot be produced in a fusion of two pomerons (two gluonic ladders). For heavy vector quarkonia the simplest possible mechanism is a photon-pomeron or pomeron-photon fusion shown in Fig.2. For light vector mesons the situation is slightly more complicated. In Ref.[2] we discussed several differential distributions for exclusive  $J/\Psi$  production in a phenomenological model. In Ref.[4] we performed a similar analysis for exclusive production of  $\Upsilon$  in the formalism of unintegrated gluon distributions. In Fig. 6 I show a compilation of the rapidity distributions for  $J/\Psi$ ,  $\Psi'$ ,  $\Upsilon$  and  $\Upsilon'$  for both Tevatron (left panel) and LHC (right panel). Both distributions obtained with bare amplitudes (dashed lines) and including absorption corrections (solid lines) are shown. More details about absorption corrections can be found in Refs.[2, 4]. The transverse-momentum integrated rapidity distribution is only mildly modified by the absorption corrections. Much bigger effects can be seen at large transverse momenta [2, 4] where the cross section is much smaller. We hope that in a near future the CDF collaboration at the Tevatron will release the experimental cross section for exclusive production of quarkonia [7].



**FIGURE 6.** Distribution in rapidity of  $J/\Psi$ ,  $\Psi'$ ,  $\Upsilon$ ,  $\Upsilon'$  (from top to bottom) for Tevatron (left panel) and LHC (right panel). The dashed line corresponds to calculation in the Born approximation and the solid line includes absorption corrections.

## CONCLUSIONS

I have briefly discussed some of our results on exclusive production of mesons at high energies. At present a direct comparison with experimental data is not possible. We expect some experimental data from the Tevatron soon. In a more distant future one may hope for experimental data from LHC.

## ACKNOWLEDGMENTS

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